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Estimates of Path Attenuation from Space-borne Radars
Using Normalized Surface Cross Section

Hyokyung Kim, Robert Meneghini and Liang Liao

INTRODUCTION

For attenuating-wavelength radars, a path attenuation estimate is important for constraining solutions in estimating rainfall rate and in providing particle size distribution (PSD) information

The TRMM-PR and GPM-DPR algorithms use a combination of the Hitschfeld-Bordan (HB) and Surface Reference Technique (SRT) approaches to correct the Z_m data.

- HB tends to work well at the lighter rain rates
- The SRT does well at moderate-heavy rain rates since the errors, primarily caused by fluctuations in the normalized surface cross section, σ^0, are independent of the rain rate
- As the GPM-DPR is a dual-frequency radar, an important question is whether the method can be improved by using dual-frequency surface data

DUAL-FREQUENCY SRT

The basic SRT is simple : the two way path attenuation estimate is obtained from a difference of σ^0 outside and inside the rain.

$$\hat{A}(f_j) = \sigma^0_{no-rain}(f_j) - \sigma^0_{rain}(f_j); \quad A(f_j) = 2\int_0^{r_{surface}} k(s, f_j)\,ds$$

For dual-freq data, it is useful to look at the difference (in frequency) of differences (rain/no-rain). This provides an estimate of the differential attenuation

$$\delta\hat{A} = A(Ka) - A(Ku) = [\sigma^0_{no-rain}(f_{Ka}) - \sigma^0_{rain}(f_{Ka})] - [\sigma^0_{no-rain}(f_{Ku}) - \sigma^0_{rain}(f_{Ku})]$$

$$\delta\hat{A} = \delta\sigma^0_{no-rain} - \delta\sigma^0_{rain}$$

$$\delta A = 2\int_0^{r_{surface}} [k(s, f_{Ka}) - k(s, f_{Ku})]\,ds$$

Error Sources

The primary error source in the SRT is the variability of the surface reference $\sigma^0_{no-rain}(f_j)$ or $\delta\sigma^0_{no-rain}$
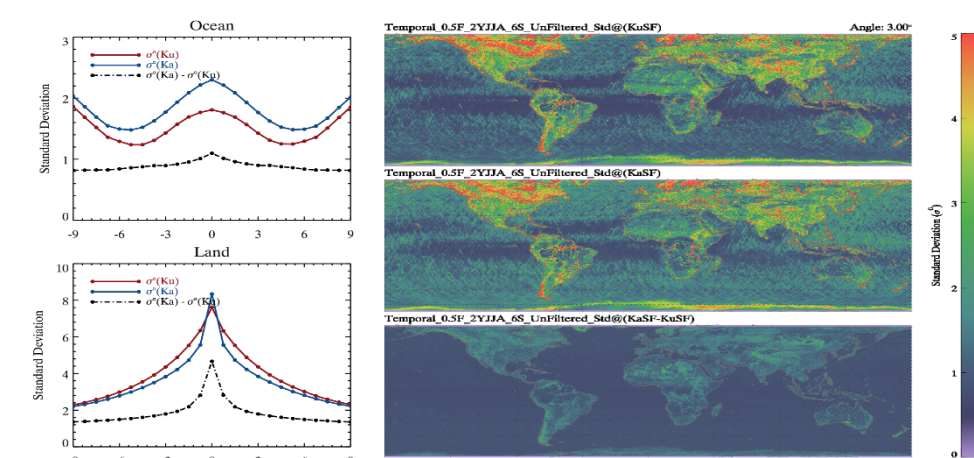

Fig. 1 Global average results show that the standard deviation of $\delta\sigma^0$ is always smaller than σ^0 at either frequency. This can also be seen in the maps of std dev[σ^0] and std dev($\delta\sigma^0$). On this basis we expect that the estimate of δA should be more accurate than A(Ka) or A(Ku)

Comparison between SRT and DSRT

DSRT PIA generally shows better fidelity than does SRT
- Less noisy with fewer negative attenuations
- Better agreement among PIA estimates when using different reference data

Errors in DSRT occur when converting δA to A(Ku) or A(Ka)
- Conversion depends on the PSD along the path
- Present DPR retrieval module (Seto & Iguchi) use δA as the constraint

DSRT has poorer dynamic range at high rain rates
- Loss of Ka-band signal from high attenuation
- Must use SRT(Ku) for A(Ku) when Ka-band surface return is lost

DSRT can only be applied to inner swath (125 km)
- JAXA may change this so that Ku/Ka-band available over full swath (250 km)
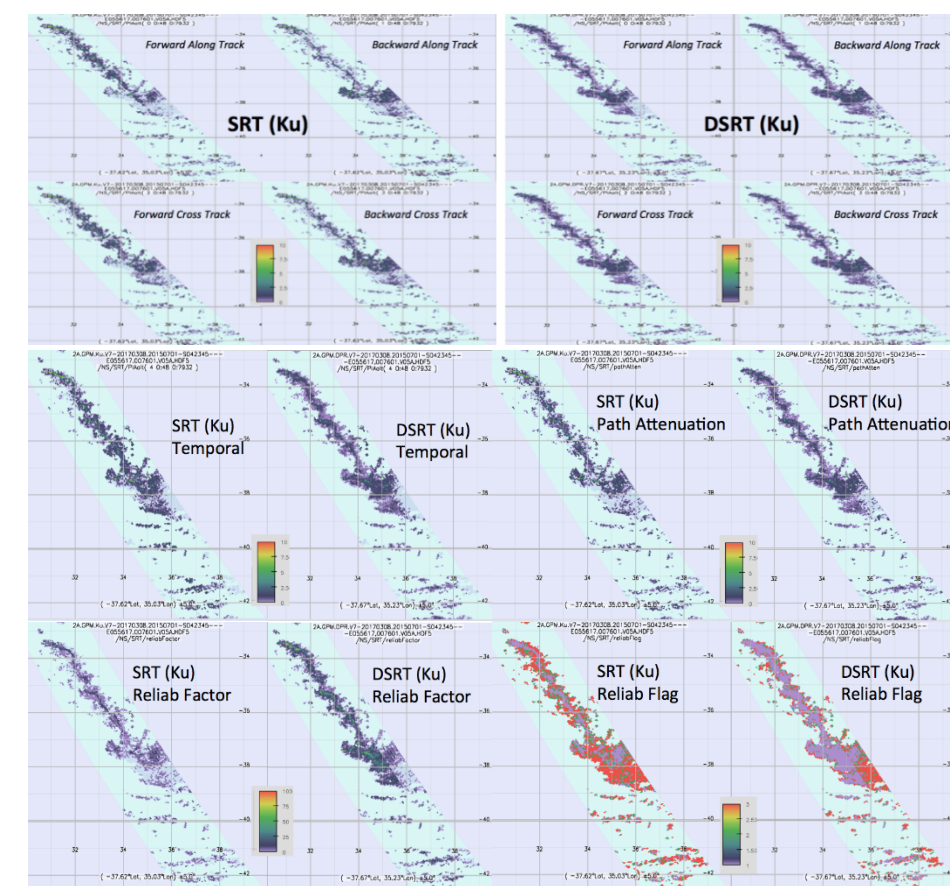
NO RAIN REFERENCE DATA ($\sigma^0/\delta\sigma^0$)

A critical factor in accurate PIA estimate is minimizing variance of reference data.

Multiple types of reference data are useful to select the most stable, to estimate the error in the PIA, and to serve as a backup when other ref data are not available (e.g., inland lakes, islands, peninsulas)

Types of Reference Data

Spatial : data are taken near the rain area
- Along-track (forward & backward)
- Cross-track (forward & backward) – ocean only

Temporal : prior rain-free measurement of σ^0
- Mean and standard deviation of σ^0, $\delta\sigma^0$ are binned into space-time-angle grid

Types of Temporal Reference Data

Fixed Grid
- Take statistics of only those σ^0 (no-rain) within the space-time-angle box
- Variance at each cell will generally decrease as box size decreases (which is what we want)
- Tradeoff between increased spatial resolution and fraction of cells with an insufficient number of samples

Variable Spatial Grid (Stepwise Expansion)
- Allow box size to expand to include sufficient number of samples
- Expand in a way that minimizes the variance of the σ^0 or $\delta\sigma^0$

Overlay Orbits
- Find orbits with nearly identical trajectories(i.e., covering the same orbit track)
- Use rain-free σ^0 (or $\delta\sigma^0$) data to form the reference data
- This data set minimizes the error caused by spatial variability in σ^0 (or $\delta\sigma^0$)
- Data also give insight into the correct surface location (along range direction) in cases of heavy attenuation
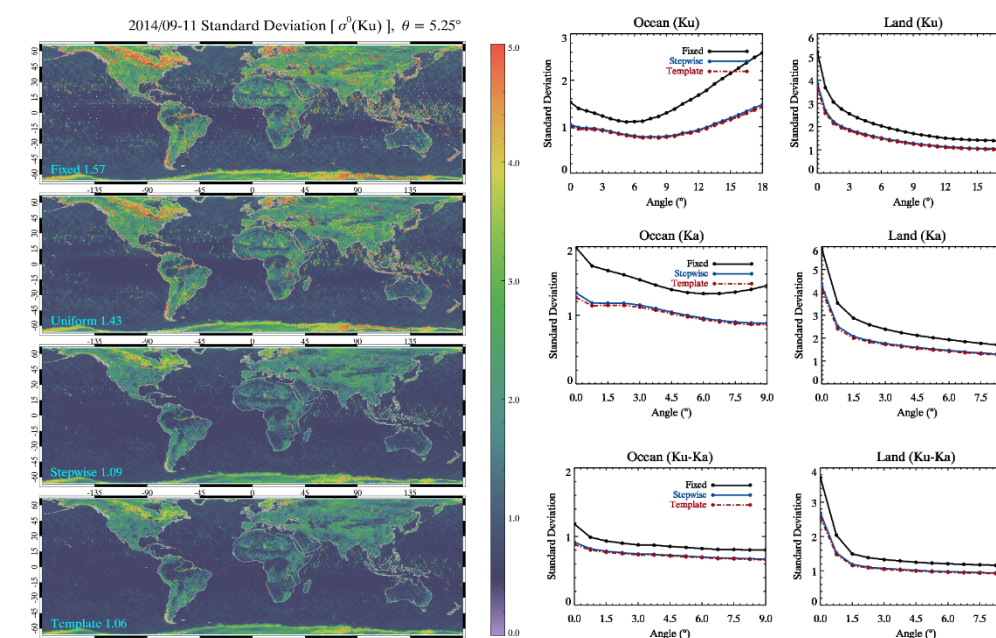
Fixed Grid vs. Variable Grid

Fig. 3. Left) Maps of the standard deviation in dB of the rain-free σ^0(Ku) data at an incidence angle of 5.25° using a fixed grid (top panel) and variable grids (bottom three panels). The global average of the standard deviation is shown at the bottom left of each panel. **Right)** Standard deviation of σ^0 (Ku, Ka and difference) in dB as a function of incidence angle and surface type.

Comparison between Overlay and Fixed grid

7 closely-matched orbits (Case A) are selected to construct a temporal reference of σ^0 (no-rain) . The std dev of these data is generally smaller than that from the fixed grid. The decrease is more significant at near nadir than off nadir. Case B (8 orbits) shows a similar decrease in the std dev.
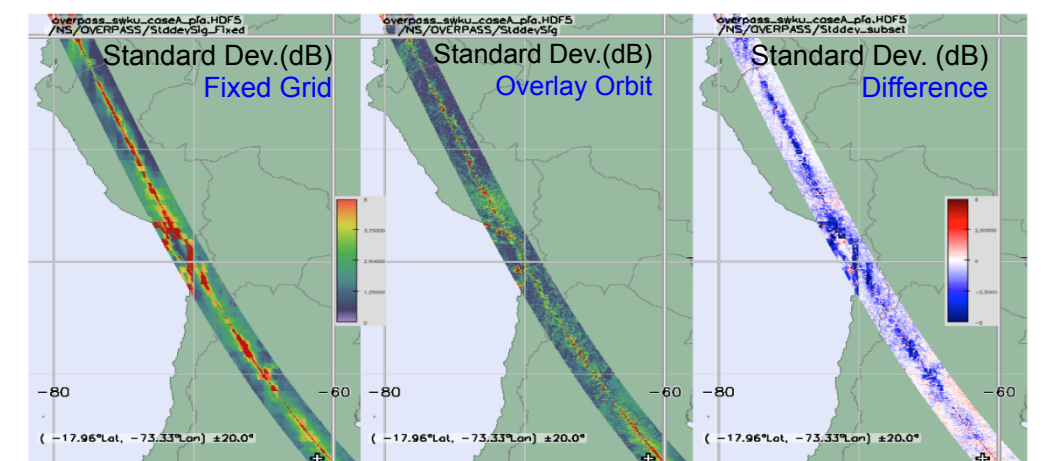
Case A : 7 overpass orbits (#6729, #2855, #3639, #11740, #12032, #6237, #7313)
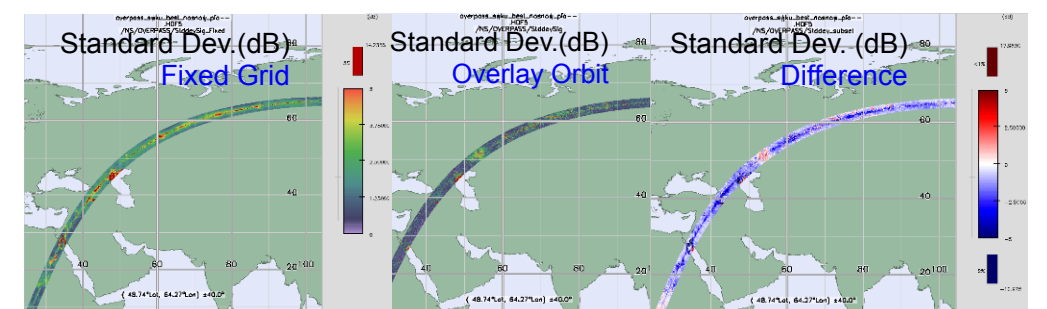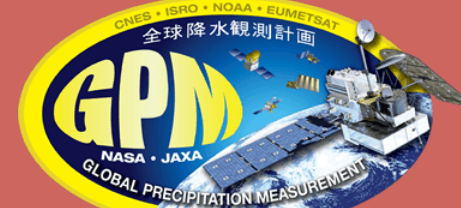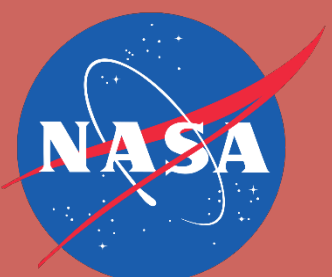

Case B : 8 overpass orbits (#8777, #13250, #6287, #6410, #14295, #16047, #3689,#2490) are used to compute the standard Deviation.

CONCLUSIONS

- Both single and dual-frequency versions of the SRT are needed to optimize the accuracy and dynamic range of the method
  - Dual-freq SRT is generally more accurate but has a smaller dynamic range than the single-freq method
- Rain-free Spatial and Temporal Reference data are needed as a baseline from which the PIA is computed
- Three types of temporal reference data have been identified and analyzed (fixed, variable & overlay)
  - Data from the overlay orbits are sometimes optimum as they minimize the spatial variability of the rain-free σ^0

ACKNOWLEDGEMENTS